Center Independent Research & Development: JPL IRAD

System Level Autonomy to Enable Autonomous Mapping Missions of Small Solar System Bodies

Completed Technology Project (2016 - 2018)

Project Introduction

Enable a novel mission capability to autonomously reach and map small solar system bodies, without the intervention of teams of ground operation personnel and equipment.

This initiative focuses on system-level autonomy. “System-level” means the coordination of many subsystem-level autonomy capabilities such as guidance, navigation and control for surface and in-space vehicles; hazard detection and avoidance; event and object identification and tracking (dust devils, stars); and vehicle health management. We will work closely with the subsystem-level collaborators to enable a more effective and efficient interaction among various functions within system resources and constraints. “Effective” refers to a more flexible overall system that can react to unplanned events and recover from failures. System-level resources and constraints typically are not managed within subsystem-level autonomy since they involve the interaction of activities in several domain areas, including power generation, storage and consumption; data storage and downlink bandwidth; thermal interactions; and conflicts between pointing needs (e.g., solar array pointing which affects power generation). System-level autonomy will provide a uniform framework that will enhance mission return by taking advantage of unused resources and by simplifying fault protection designs.

Our approach to accomplish system-level autonomy is to establish a set of architectural principles, realize an architecture, and demonstrate a reference application to mature it into certified flight and ground system components. From among the possible state-of-the-practice approaches, this initiative selects elaborated behavior models combined with model-based component fault diagnostics using shared state data as the most feasible method of providing the essential autonomy capabilities for a broad range of current and future missions. Using declarative models expressed explicitly in relevant behavior concepts provides a more intuitive description of what a system can, can’t, should, or shouldn’t do compared to specifications like pseudo-code, flow-charts and state machines, which encode a designer's pre-determined decision space with normal tie to concepts like resource constraints, timing deadlines, or dependencies.

The initiative adopts a modular approach in which low-level system commands are generated by an execution engine from task network models, which in turn are generated by a planner/scheduler from a model of the system's operations constraints, states, and objectives. The planner/scheduler may be integrated as part of the autonomous system, enabling use of a very high level control interface, or it can be retained on the ground with uploaded task networks as the control interface. As well as providing an innovative scalable level of autonomy, this modular approach enables an incremental development path for this initiative. The initiative will ensure compatibility with the partitioned space and time architecture of JPL’s Flight Software Core product and with its Small Scale software framework, and their respective

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ground interfaces to the extent as appropriate.

During development of the initial flight/ground system components, we will:
• Identify the needs and challenges of particular approaches developed by the autonomy users' community;
• Identify specific properties and needs of technologies that enable subsystem-level autonomy capabilities, for integration into the new flight/ground architecture;
• Define coordinating behaviors and interfaces that constitute the system-level framework;
• Adapt current flight/ground system components, and autonomy technologies to allow integration into the system level framework;
• Coordinate development of ground and flight system and software components to enable a migration of capabilities from ground to flight.

The novel approach develops a framework based on elaborated behavior models, enables the integration of a number of technologies, and accommodates their interactions and resource constraints. We will integrate existing autonomy technologies into a flight-like testbed under a new architecture to demonstrate the compatibility of these technologies within a flight-like environment, without requiring complete redevelopment of these technologies. We also will show how to integrate new autonomy technologies into the architecture. The initiative will
• Develop a framework for effective interaction between the planner/scheduler, execution engine, and low level commanding to allow a system to flexibly execute activities and respond to unplanned events;
• Use that mechanism to integrate subsystem autonomy capabilities with health management and planning/scheduling to respond logically to unplanned events.

We focus on a proximity operations mission concept initially because it addresses a significant gap in capability for future micro-gravity missions. The system-level autonomy framework can also be generalized to other space assets and flight configurations including orbiters, landers, etc. We will demonstrate how the framework can be used to handle mundane, off-nominal, and unexpected mission events.

Anticipated Benefits

Task Networks provide easier implementation of fail-operational and opportunistic science collection capability of NASA missions.

Task Networks would enable execution of future low-altitude small-body mapping operations that would otherwise be too risky to attempt especially with a reliance on ground-in-the-loop.

Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Jet Propulsion Laboratory (JPL)

Responsible Program:

Center Independent Research & Development: JPL IRAD

Project Management

Program Manager:

Fred Y Hadaegh

Project Manager:

Fred Y Hadaegh

Principal Investigator:

Kevin J Barltrop

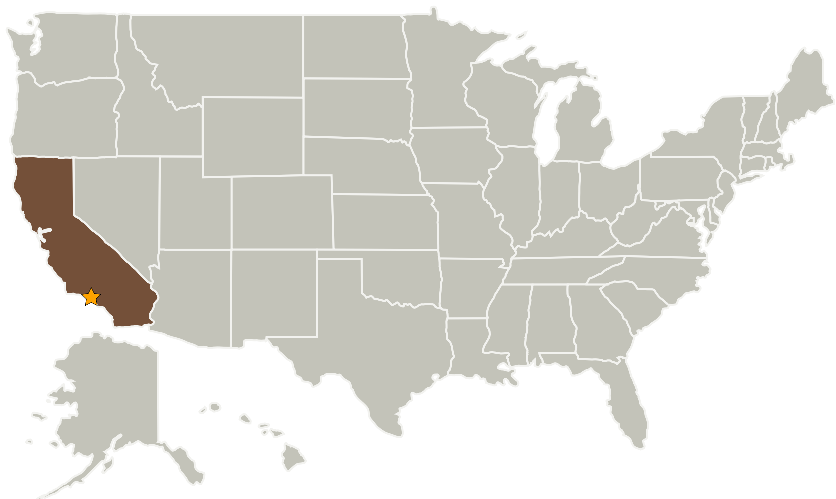
Co-Investigator:

Lorraine M Fesq

Commerical imaging satellites may also benefit from the improved system and the flexibility to observe events using this approach.

Unexpected and opportunistic event observations such as for Earth orbiting satellites at NOAA or NASA would become easier to obtain using this technology.

Primary U.S. Work Locations and Key Partners

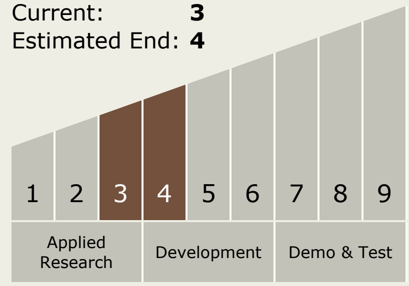


Organizations Performing Work	Role	Type	Location
★Jet Propulsion Laboratory(JPL)	Lead Organization	NASA Center	Pasadena, California

Primary U.S. Work Locations
California

Technology Maturity (TRL)

Start: **3**
Current: **3**
Estimated End: **4**



Technology Areas

Primary:

- TX10 Autonomous Systems
  └ TX10.2 Reasoning and Acting
    └ TX10.2.2 Activity and Resource Planning and Scheduling

Target Destination

Earth

Supported Mission Type

Push

Images

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(https://techport.nasa.gov/image/28003)